THE **BOEING** COMPANY
AERO-SPACE DIVISION
SATURN BOOSTER BRANCH

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VOLUME ______ OF ______

TITLE METALLURGICAL ANALYSIS OF FILTER HOUSING ASSEMBLY,
60B83104-1, SERIAL NUMBER 69 FAILURE

MODEL NO. ~~Saturn V/S-~~ IC CONTRACT NO. NAS8-5608

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ABSTRACT

As reported in UER U243590 and UER U214047 on September 8, 1966 Filter Housing Assembly, 60B83104-1, Serial 69 was discovered leaking from a defect in the side of the housing. The housing is 7075-T6 aluminum alloy and is manufactured by Hydraulics Research and Manufacturing Company. Examination of the fracture pattern and material microstructure led to the conclusion that failure was by stress corrosion cracking. Future failures of the part by stress corrosion cracking can be avoided by heat treating the housing to a T73 temper .

LIST OF KEY WORDS

60B83104-1

Filter Housing Assembly

Stress Corrosion Cracking

Aluminum Alloy 7075

T73 Temper

U3-4071-1000

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LIST OF FIGURES

1.0 OBJECT

The object of this study was to determine the cause of failure of Filter Housing Assembly, 60B83104-1 serial number 69.

2.0 BACKGROUND

As reported in Unplanned Event Records U243590 and U214047 on September 8, 1966 the housing of Filter Housing Assembly, 60B83104-1 serial number 69 was discovered leaking. Penetrant inspection revealed a crack about 7/8 inch long in the housing adjacent to the boss which contains the pressure sensing ports. Analysis was requested in AAR 243590-1, dated October 6, 1966.

This assembly is manufactured by Hydraulics Research and Manufacturing Company, Burbank, California. The housing is machined from a 7075 aluminum alloy forged rectangular block, procured per 60B32043. The housing was machined to within 0.125 inch of final dimensions and given a final heat treatment consisting of solutioning and aging to the T6 temper.

The assembly was installed on the 504 vehicle. Except for acceptance testing, the assembly had seen no use. The vendor reported no unusual happenings during manufacture which would account for a premature failure of the housing.

3.0 CONCLUSION

It is concluded that a crack developed and progressed from the inside of the filter cavity to the outside of the filter housing by stress corrosion cracking. Failure was precipitated by residual stresses developed during heat treating of the housing.

4.0 RECOMMENDATIONS

It is recommended that the housing of the Filter Housing Assembly, 60B83104-1 be heat treated to a final temper of T73, as long as strength requirements are met. The change from T6 temper to T73 temper increases the minimum stress corrosion threshold from 7,000 psi to greater than 48,000 psi. Residual stresses due to heat treating are not expected to exceed the minimum T73 stress corrosion threshold.

5.0 PROCEDURES AND RESULTS

5.1 To determine the cause of cracking tests consisted of visual examination, penetrant inspection, fractography, microscopic examination, hardness testing, conductivity tests, chemical analysis and residual

5.1 (Continued)

stress measurements.

5.2 Upon receipt of the Filter Housing Assembly at the M and P Laboratory the housing was visually examined to determine the possible areas of failure. A fluorescent dye penetrant inspection was made on all exterior and interior surfaces in accordance with 60B32002 to determine the extent of cracking. The housing was then sectioned to expose the crack found during inspection. A portion of the fracture face was then examined in the region believed to be the initial region of crack formation. Different types of fractures will exhibit characteristic fracture faces, indicating the possible cause of failure. Two microspecimens were prepared, one radial and one longitudinal. Viewing these specimens under high magnification determines the fracture mode along with any anomalies which might exist in the grain structure of the material. A hardness traverse was taken on the radial microspecimen. These measurments indicate the uniformity of hardness through the cross section of the part. Hardness combined with a conductivity measurement gives the heat treatment temper of the alloy. Hardness readings were taken on a Tukon Hardness Tester using a 500 gram load and a Knoop indenter, and on a Wilson Rockwell Hardness Tester using the B scale. Conductivity was determined using the principle of eddy currents to measure the electrical conductivity of nonmagnetic alloys. A sample of material was submitted to the Quality Control Laboratory for a spectroscopic chemical analysis. Another sample was sent to the Materials and Processes Group in Seattle for residual stress measurements on the interior and exterior surfaces of the housing adjacent to the failed area. These values should give some measure of the residual stresses induced by heat treatment.

5.3 Visual examination of the housing found the only defect to be the 7/8 inch long crack on the exterior surface, along with the interior projection of the crack which was about 2 inches long. Penetrant inspection revealed the only defect to be that found by visual inspection. The location of the defect is indicated in view A of figure 1. Figure 2 shows the results of penetrant inspection. Figure 3 shows the exterior surface at the crack location. It is noted that the crack is not continuous. Figure 4 shows the interior surface at the crack location. It can be seen that the failure is a series of cracks all running longitudinally.

Figure 5 is a fractograph of a portion of one of the cracks. The initiation point of this crack, on the interior surface of the housing is indicated in figure 5. The fracture face has a granular

5.3 (Continued)

exfoliated appearance. It was noted that when this specimen was cut out the remaining cracks closed. This indicates that there was a tensile residual stress in the part normal to the plane of fracture. The appearance of the fracture indicates that failure progressed from the interior of the housing radially outward.

Similar results were obtained from the examination of both radial and longitudial microspecimens. Figure 6 shows the radial microspecimen unetched, while figure 9 shows the unetched longitudinal microspecimen. The microstructure is typical of an aluminum alloy hand forged block not having a great deal of prework. This is evidenced by the failure of some grains to recrystallize and the presence of stringers of agglomerated particles of secondary phases. However, this is not considered unusual for large hand forged blocks. Figures 7 and 8 show the failure in a radial section. This is the short transverse - longitudinal grain direction plane. Figure 10 shows the failure in a longitudinal section. This is the long transverse - longitudinal grain direction plane. Cracking is noted to be intergranular and branching in a plane normal to the short transverse grain direction. Microscopic study revealed a network of cracks and subcracks which comprise the failure. The failure pattern observed is characteristic of stress corrosion cracking.

Hardness was found to be relatively uniform across the thickness of the part. The average of six Knoop readings was 160, while the average of six Rockwell readings was 81 on the B scale. Conductivity was measured at 32.5% IACS. Spectroscopic analysis confirmed the alloy to be 7075. while hardness and conductivity confirmed the temper to be T6, although the hardness readings were slightly below those expected for T6. Residual stress measurements found an internal surface compressive stress of 8,000 psi circumferentially: and an external compressive stress of 15,000 psi circumferentially. These values were obtained with an accuracy of about ± 5,000 psi.

The variance in residual stresses is caused by differential cooling during quenching. The filter cavity received insufficient cooling fluid to reduce the temperature at the inside surface as rapidly as the outside surface. The geometry of the housing at the region of failure contributed to tensile stresses on the internal surface of the filter cavity. The results of the residual stress measurements indicates stresses were relieved by sectioning, since the

5.3 (Continued)

stresses found were not of great enough magnitude to cause failure.

The cause of failure is attributed to stress corrosion cracking, initiating on the inside surface of the filter cavity and progressing radially outward. The conclusion is drawn from the following reasons:

1. Discontinuous nature of cracking.

2. Granular appearance of fracture face.

3. Intergranular mode of failure.

4. Branching network of cracks.

5. Grain orientation.

6. Residual stresses noted in part.

7. Susceptibility of 7075-T6 aluminum alloy to stress corrosion cracking.

8. Delayed nature of failure.

9. History of part.

Corrosive attack can come from moisture entrapped during anodizing. Failures of this type have been reported by Rutemiller and Sprawls in "Stress Corrosion Of Aluminum - Where To Look For It, How To Prevent It". They report that the two factors necessary for stress corrosion cracking, corrosive attack and sustained tensile stress are present in parts of this type. Anodizing alone is not adequate protection against stress corrosion cracking.

6.0 REFERENCES

60B83104-1

UER U243590, September 23, 1966

UER U214047, September 27, 1966

AAR 243590-1, October 6, 1966

Rutemiller, H. C. and Sprowls, D. O.; "Stress Corrosion of Aluminum - Where To Look For It, How To Prevent It", Aluminum Company of America, 1962.

Coordination Sheet RU-1-598

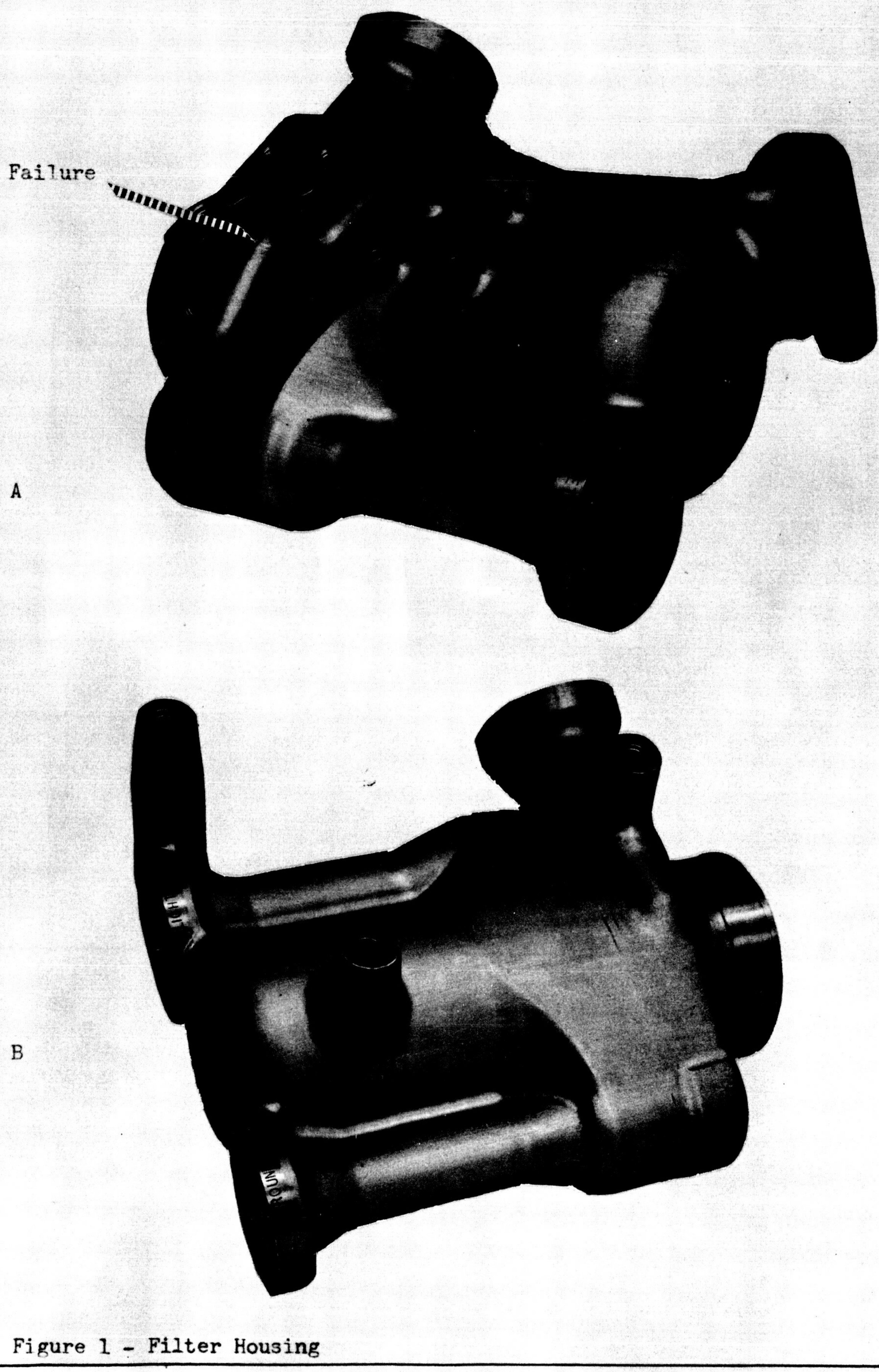
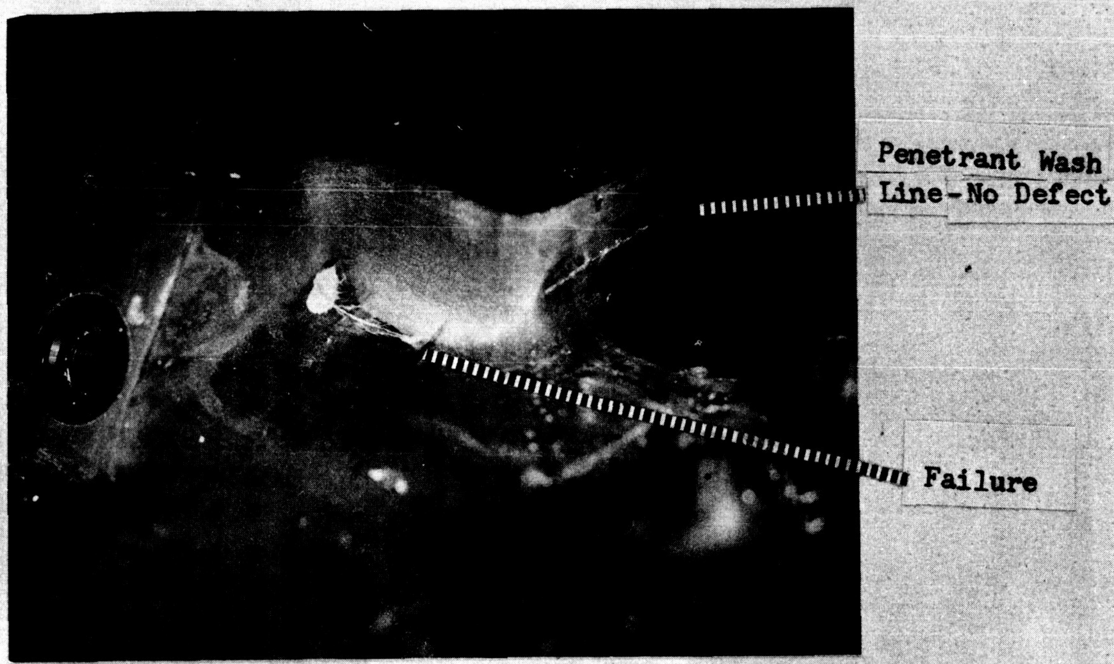
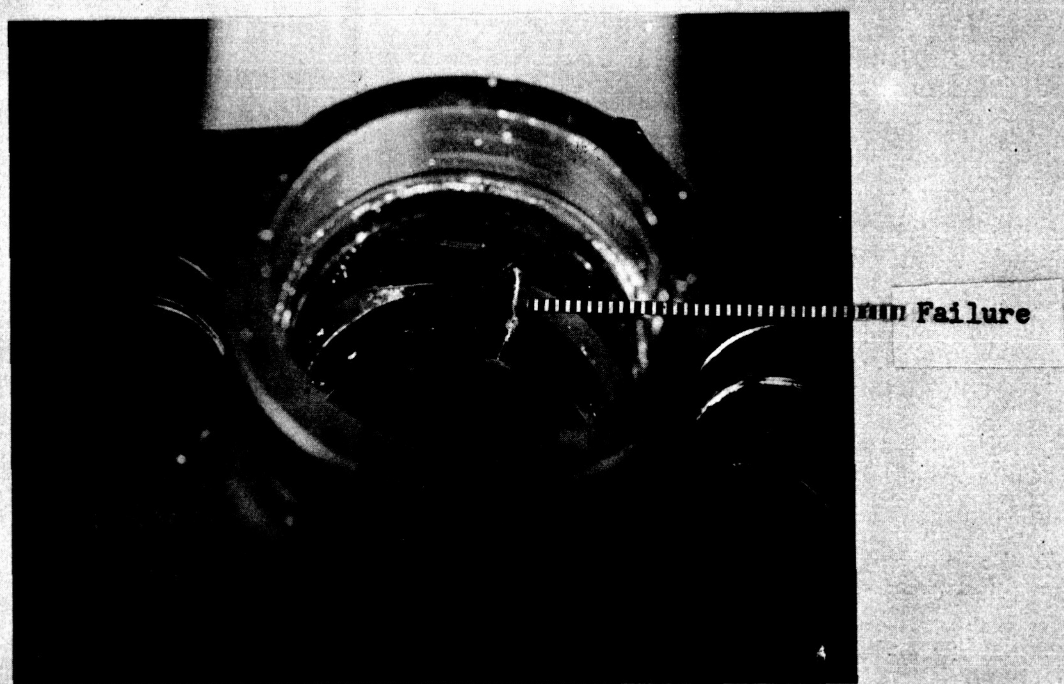


Figure 1 - Filter Housing

U3-4071-1000

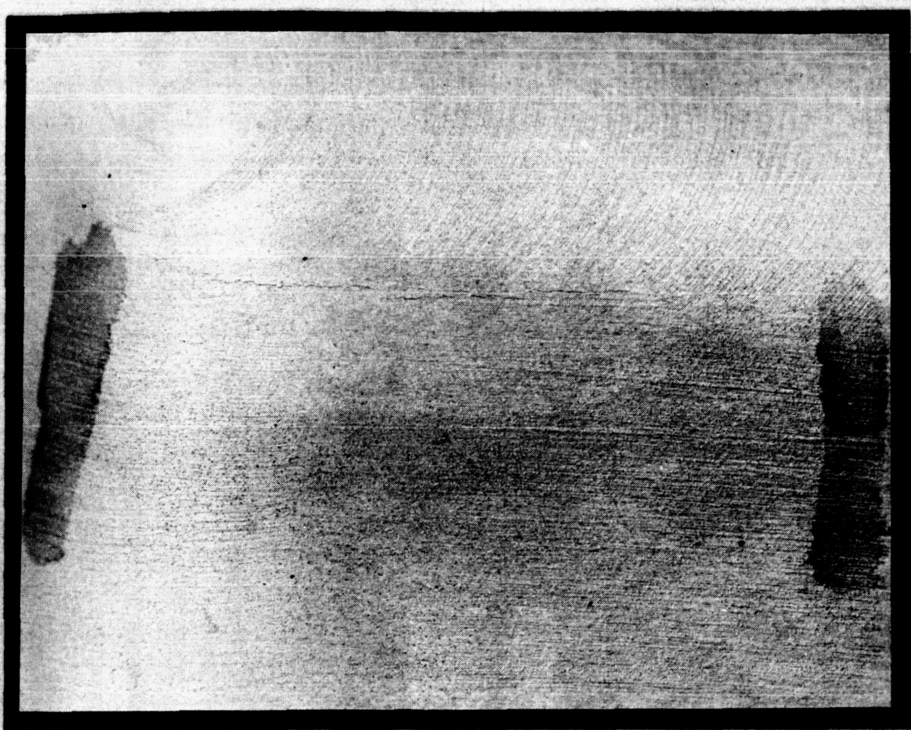


A-Exterior view of Failure

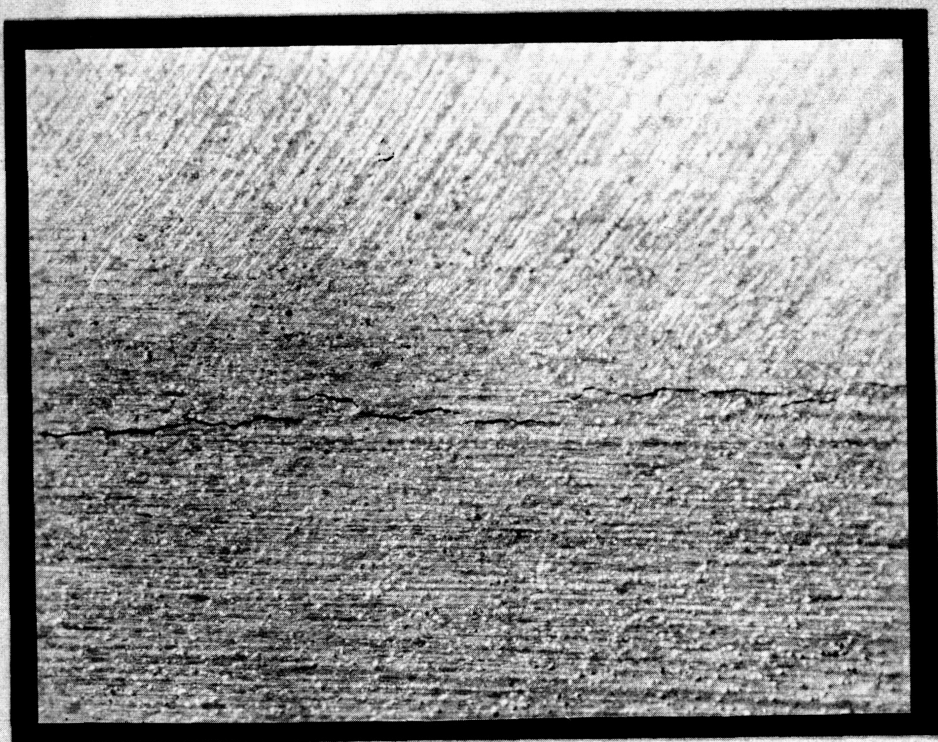


B-Interior View of Failure

Figure 2 - Results of fluorescent dye penetrant inspection

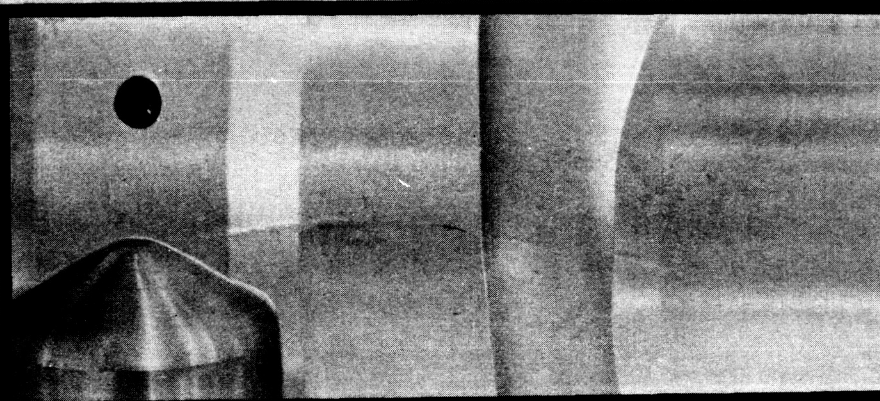


A - Exterior surface of failure, 4X

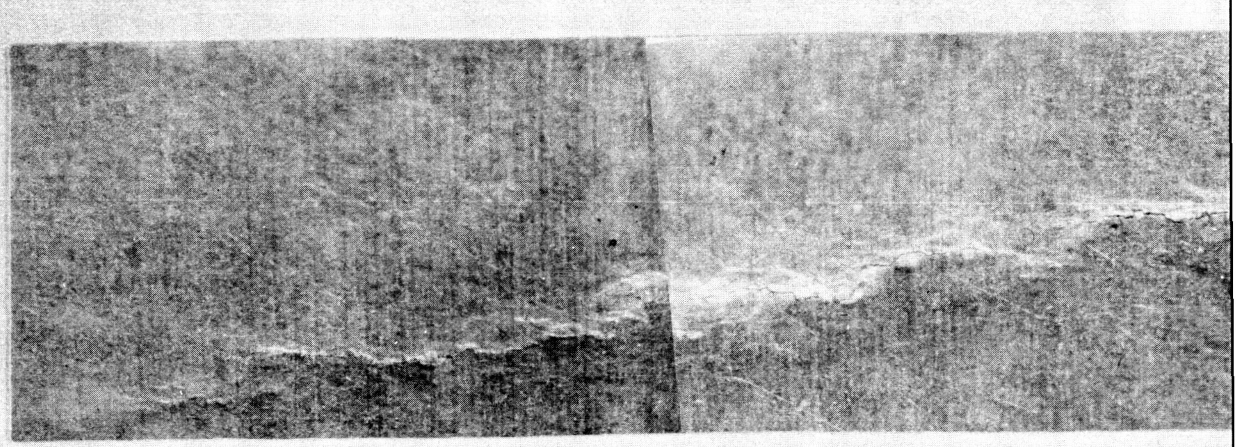


B - Portion of exterior surface of failure, 15X

Figure 3 - Exterior Surface of Failure

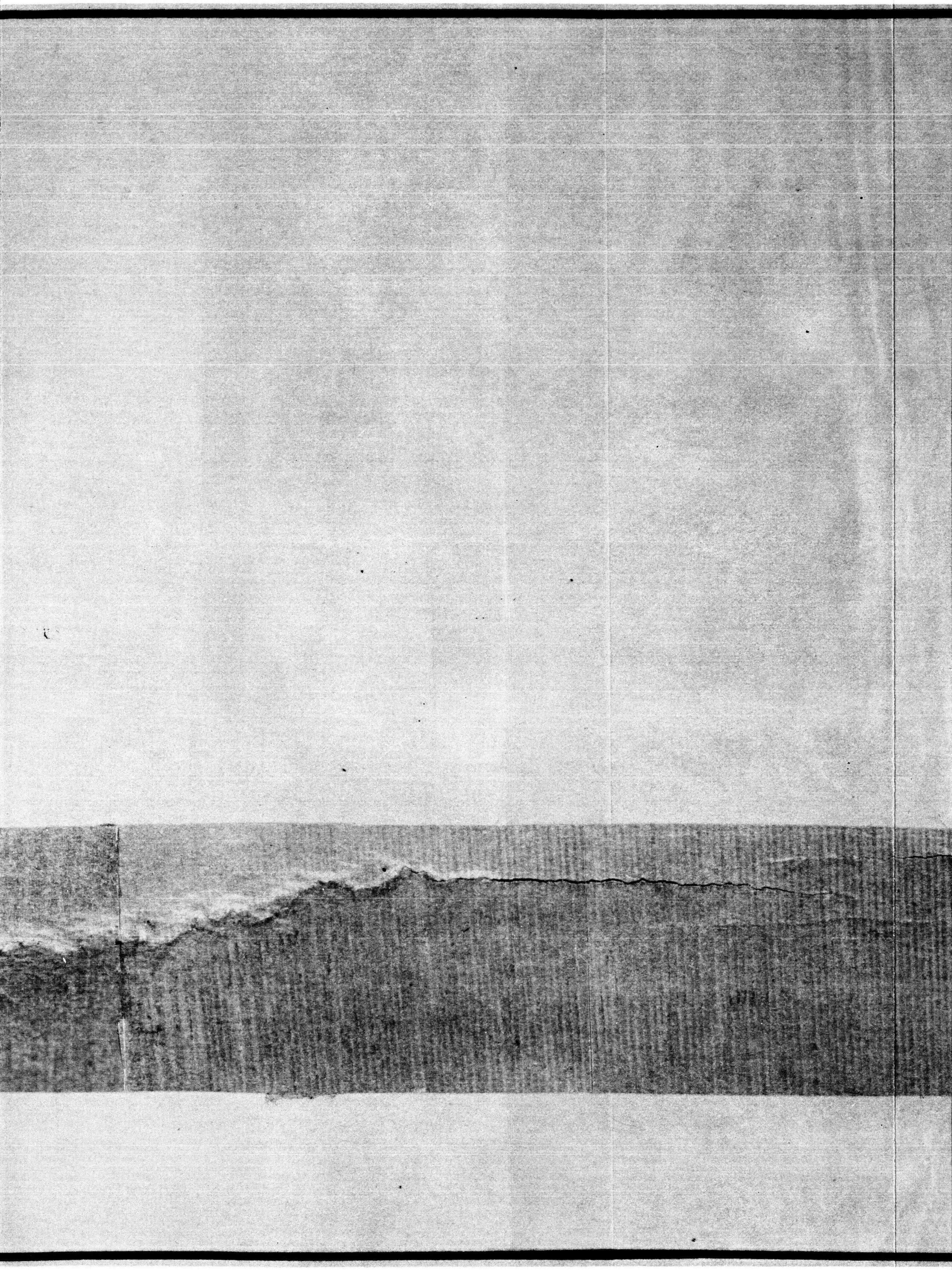


A-1X



B-15X

Figure 4 - Interior Surface of Failure



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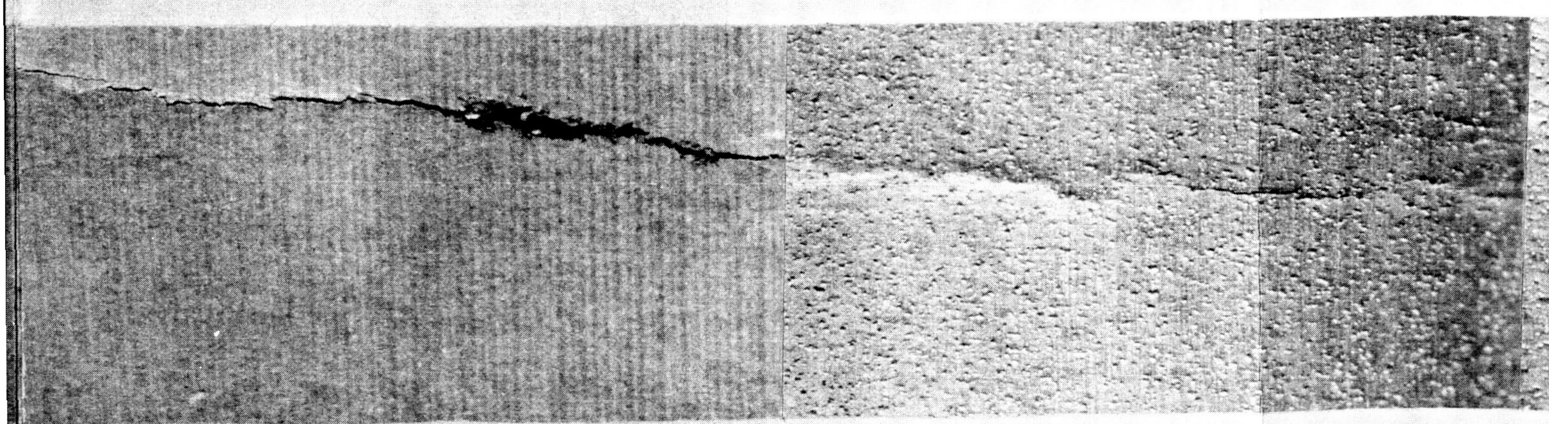
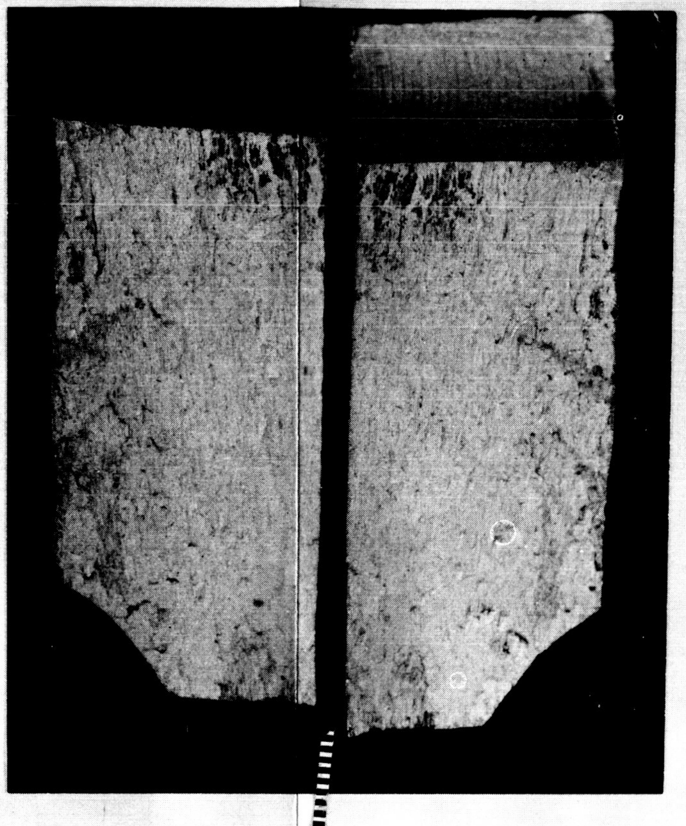




Initiation

Figure 5 - Fractograph of Portion of Crack, 3X

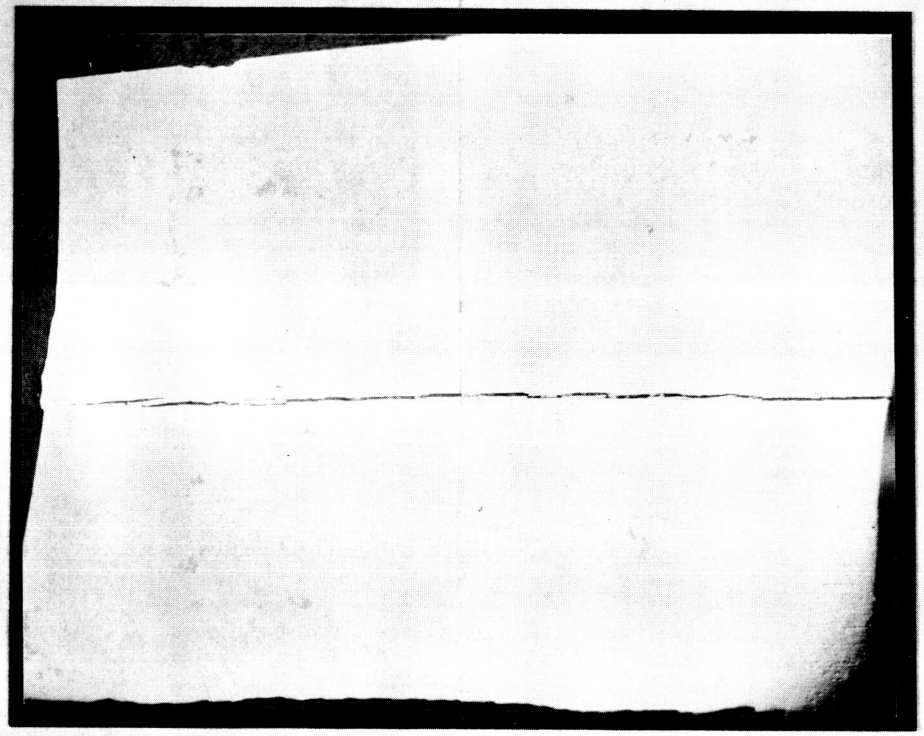
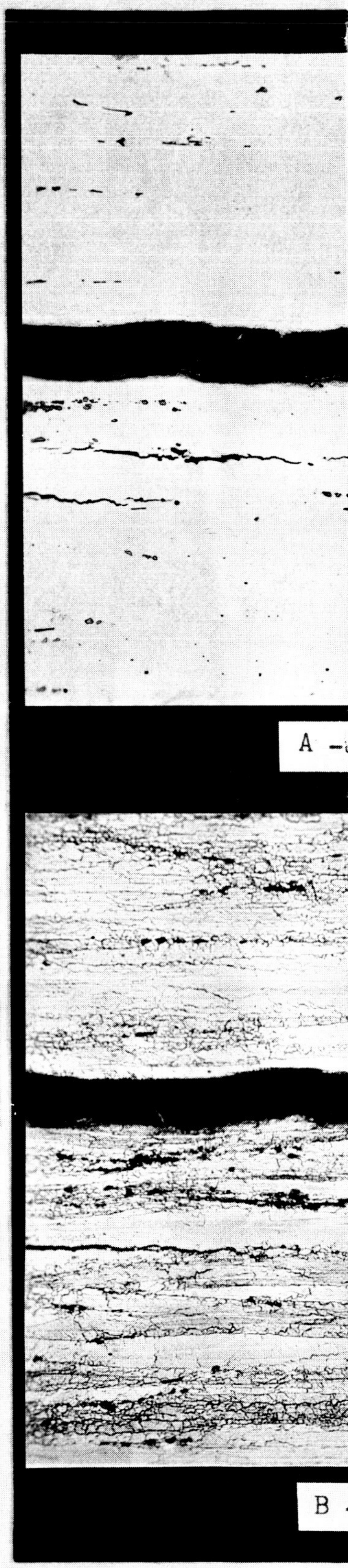


Figure 6 - Radial Microspecimen,
as polished, 6X



A -

B

Figure 7 - Mic

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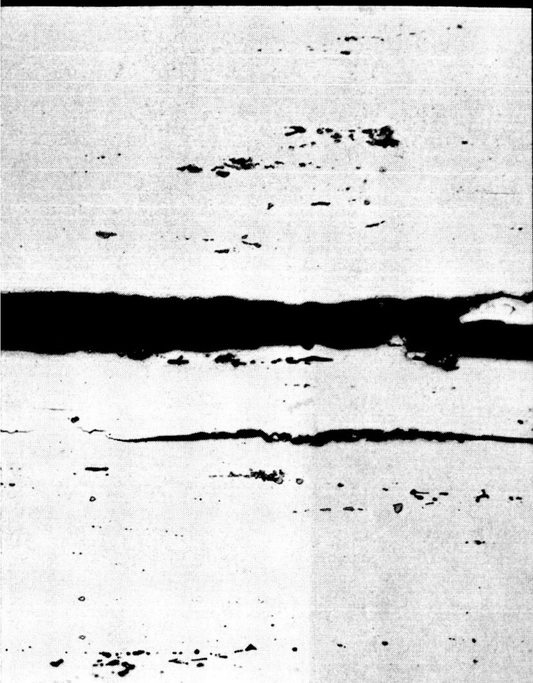
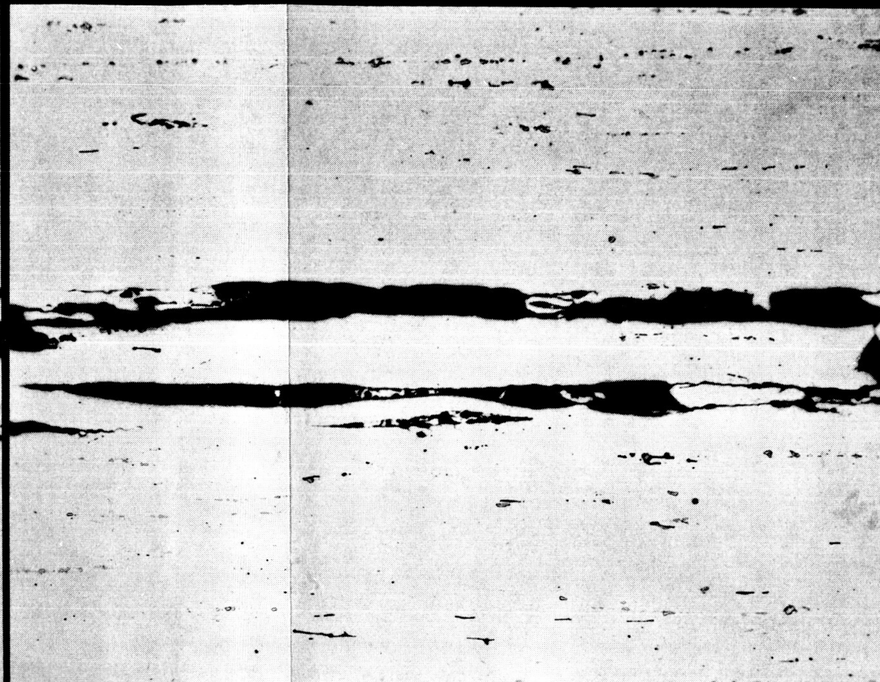
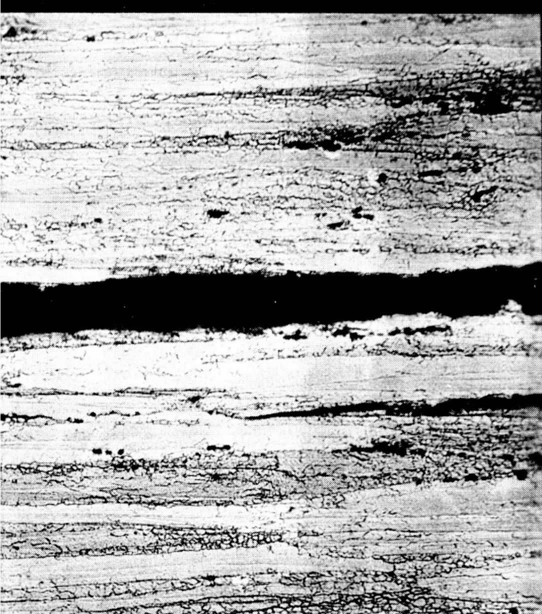


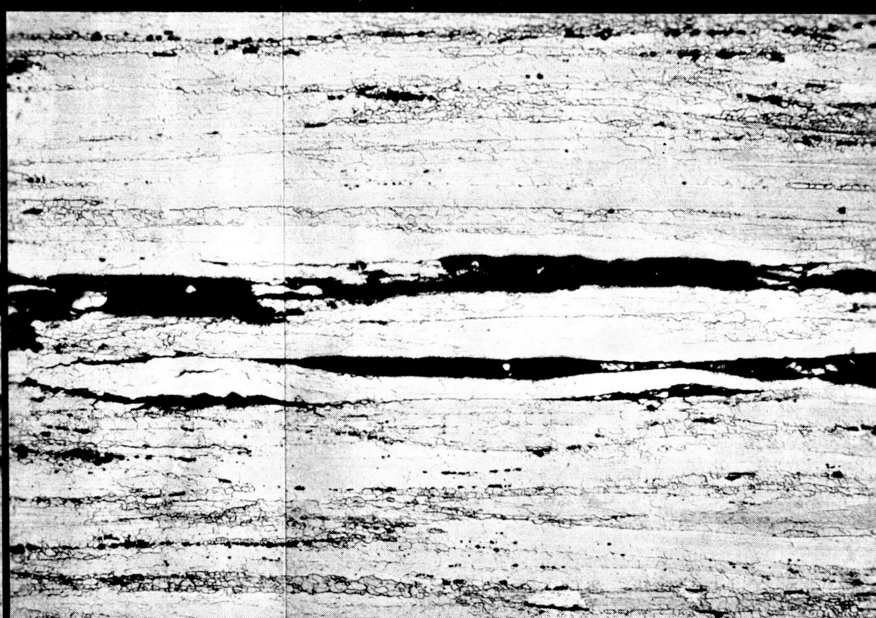
As polished, 100X



C - As polished, 100X

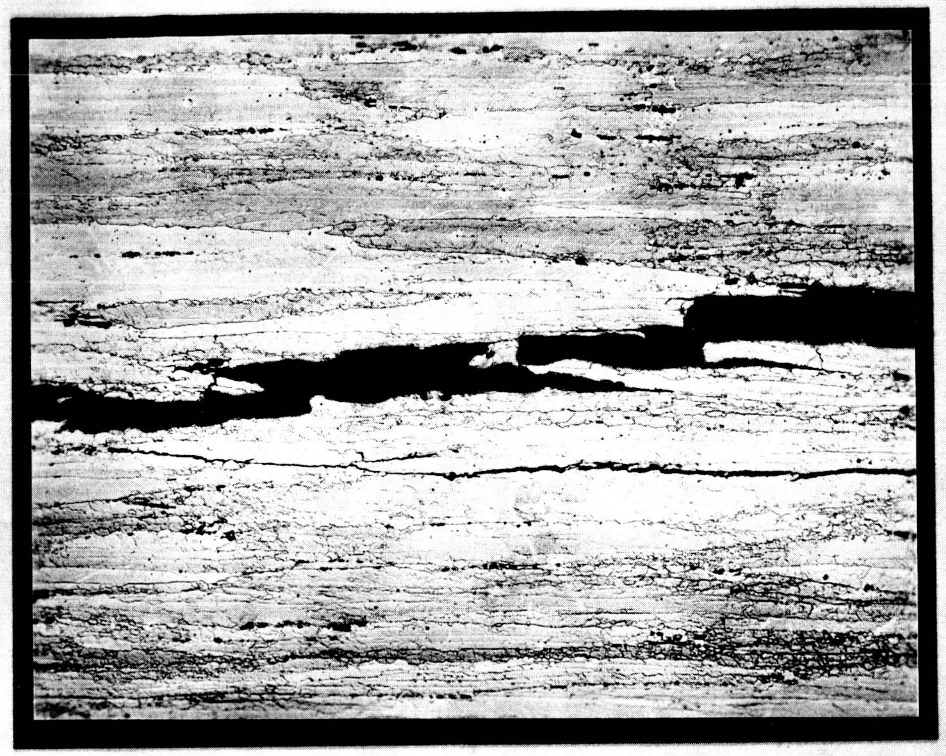


- Kellers etch, 100X

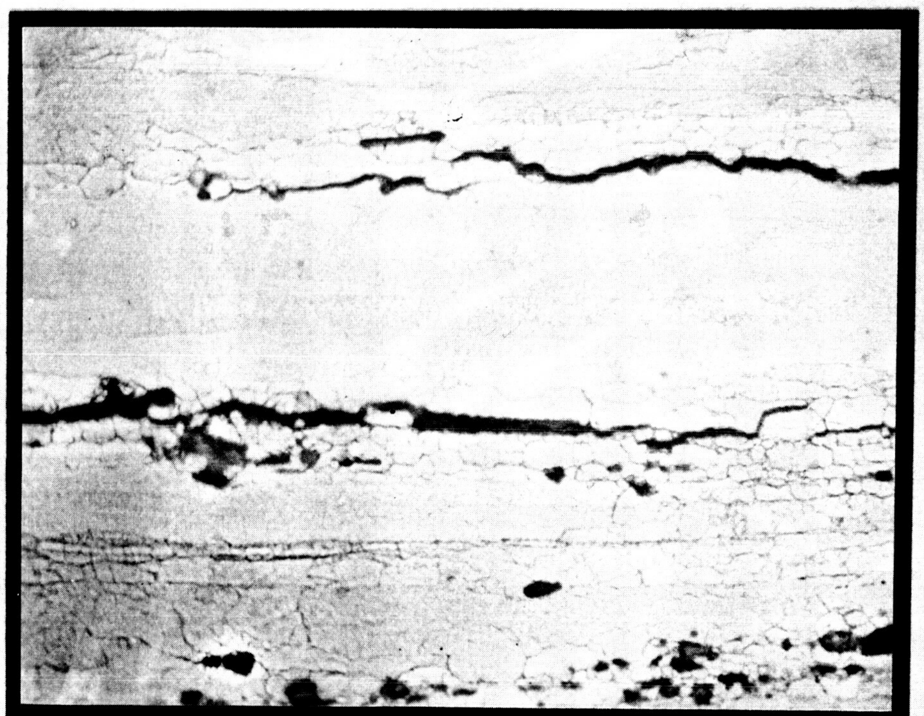


D - Kellers etch, 100X

rostructure of radial specimen



A - Kellers etch, 100X



B - Kellers etch, 500X

Figure 8 - Microstructure of radial specimen

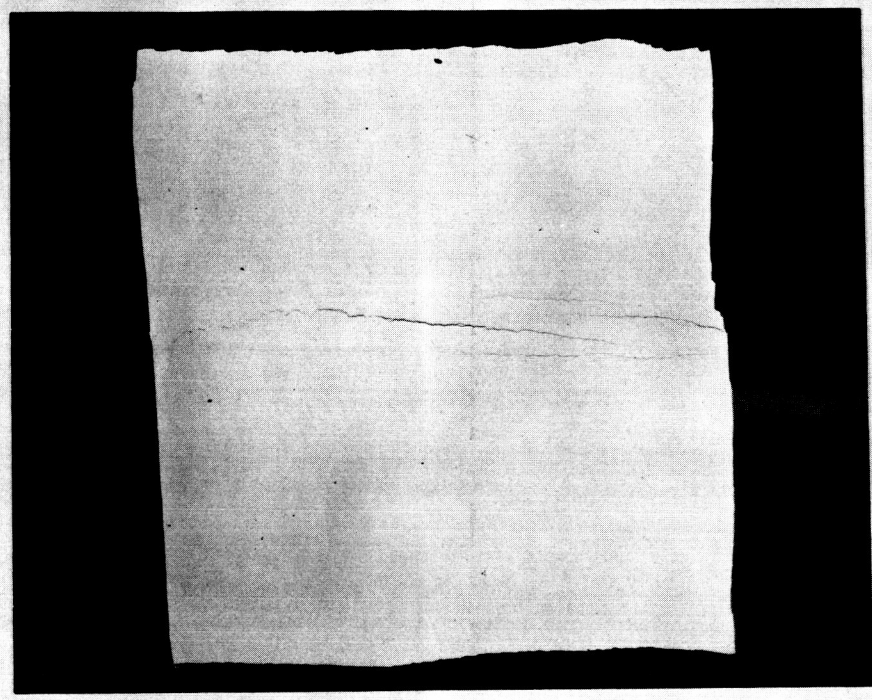


Figure 9 - Longitudinal Microspecimen
as polished, 6X

Figure 10

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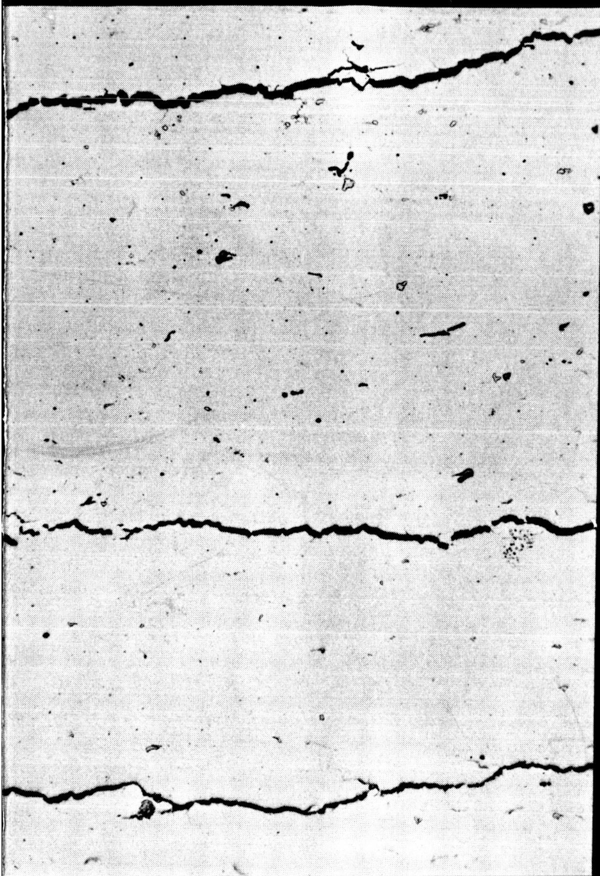

A - As polished, 100X

B - Kellers etch, 100X

C - Kellers etch, 500X

- Microstructure of Longitudinal Specimen